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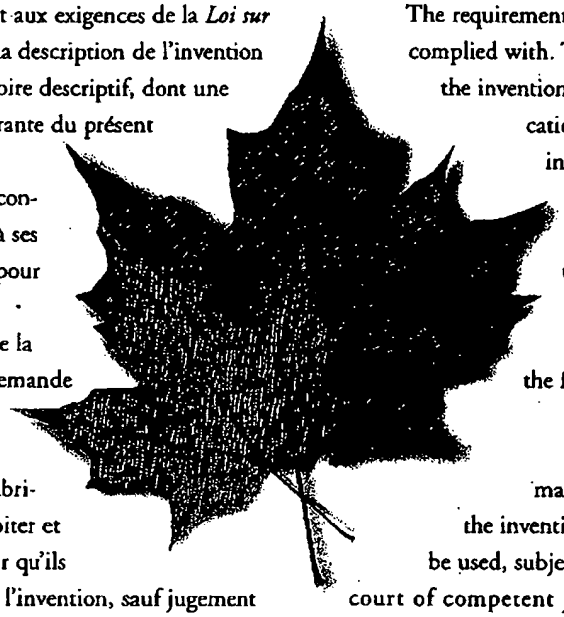
Brevet canadien / Canadian Patent

Le commissaire aux brevets a reçu une demande de délivrance de brevet visant une invention. Ladite requête satisfait aux exigences de la *Loi sur les brevets*. Le titre et la description de l'invention figurent dans le mémoire descriptif, dont une copie fait partie intégrante du présent document.

Le présent brevet confère à son titulaire et à ses représentants légaux, pour une période expirant vingt ans à compter de la date du dépôt de la demande au Canada, le droit, la faculté et le privilège exclusif de fabriquer, construire, exploiter et vendre à d'autres, pour qu'ils l'exploitent, l'objet de l'invention, sauf jugement en l'espèce rendu par un tribunal compétent, et sous réserve du paiement des taxes périodiques.



The Commissioner of Patents has received a petition for the grant of a patent for an invention. The requirements of the *Patent Act* have been complied with. The title and a description of the invention are contained in the specification, a copy of which forms an integral part of this document.

The present patent grants to its owner and to the legal representatives of its owner, for a term which expires twenty years from the filing date of the applica-tion in Canada, the exclusive right, privilege and liberty of making, constructing and using the invention and selling it to others to be used, subject to adjudication before any court of competent jurisdiction, and subject to the payment of maintenance fees.

BREVET CANADIEN **2,162,029** CANADIAN PATENT

Date à laquelle le brevet a été accordé et délivré	**2003/04/08**	Date on which the patent was granted and issued
Date du dépôt de la demande	**1994/05/03**	Filing date of the application
Date à laquelle la demande est devenue accessible au public pour consultation	**1994/11/10**	Date on which the application was made available for public inspection

Commissaire aux brevets / Commissioner of Patents

Canada

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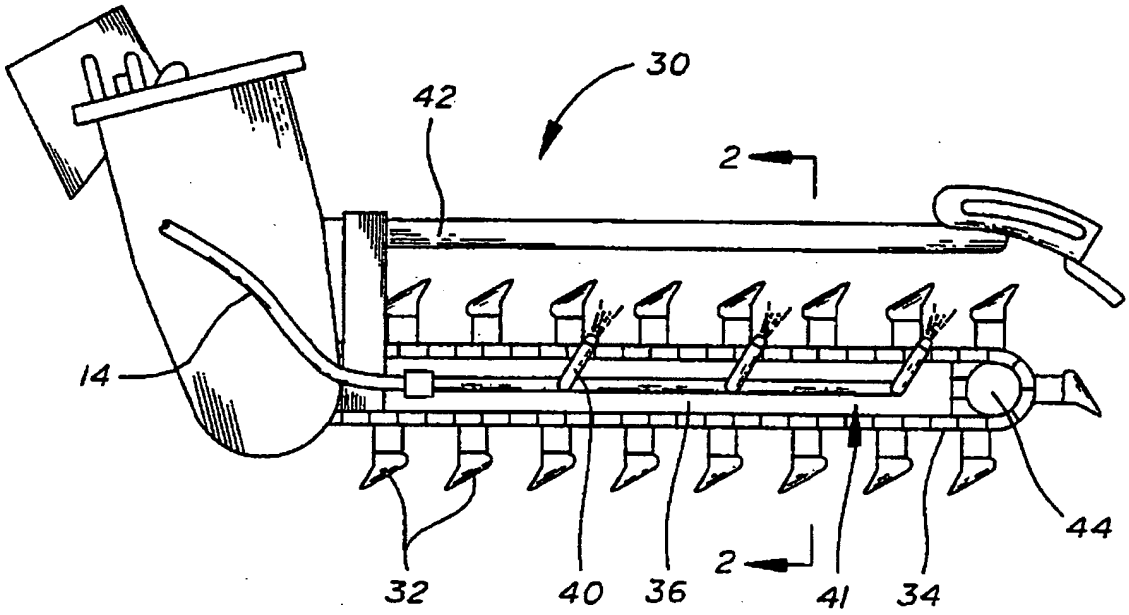

(57) Abrégé/Abstract:
Contaminated material such as soil or sludge is remediated by injecting a suitable remediation fluid into the material during excavation of the contaminated material with a trenching tool. The remediation fluid is injected into the contaminated material through an injection means, preferably a plurality of injection nozzles positioned along the length of the trenching tool. The thus treated material is backfilled or deposited directly into the trench excavated by trenching tool thereby obviating the need for off-site disposal. The constituent remediation agents in the remediation fluid may be adjusted to adapt to varying site conditions and contaminants. The remediation fluid may also be heated to accomplish volatile stripping of the contaminated material or to activate microbial agents in a low temperature environment.

METHOD AND APPARATUS FOR IN SITU SOIL REMEDIATION

Field Of The Invention

The invention relates to a method and an apparatus for the in situ remediation of contaminated soil or sludge.

Background Of The Invention

It is widely recognized that years of unregulated industry have produced numerous environmentally hazardous sites throughout the country and the world which pose substantial health hazards to world's population. In recent years, efforts to clean up or remediate environmentally contaminated sites have increased dramatically, and numerous methods and devices for cleaning up or disposing of environmental contamination have been devised or proposed. However, the magnitude of the environmental problems is enormous, but the resources available to solve the problems are limited. Therefore, there is an urgent need for methods of remediation that are relatively uncomplicated, may be rapidly implemented, and are technically and cost effective.

Therefore, it is an object of this invention to provide a cost effective, relatively rapid method of remediating environmentally contaminated sites.

It is another object of this invention to provide a highly mobile apparatus for remediating environmental contaminants.

It is yet another object of this invention to provide a method of remediating contaminated soil in situ and without

removal or disposal of the treated or contaminated material.

It is yet another object of the invention to provide a method that is capable of remediating contaminated soils and sludges in a continuous, in contrast to a batchwise, manner.

It is yet another object of the invention to provide a remediation apparatus and method which may be used on highly unstable soils and in tight quarters such as in the basements of buildings or near above-ground or below-ground storage tanks.

The above objects and advantages of the present invention will become more apparent when reference is made to the following description taken in conjunction with the accompanying drawings.

Summary Of The Invention

Contaminated material such as soil or sludge is remediated by injecting a suitable remediation fluid into the material during excavation of the contaminated material with a trenching tool. The remediation fluid is injected into the contaminated material through an injection means, preferably a plurality of injection nozzles positioned along the length of the trenching tool. The thusly treated material is backfilled or deposited directly into the trench excavated by the trenching tool thereby obviating the need for off-site disposal. The constituent remediation agents in the remediation fluid may be adjusted to adapt to varying site

conditions and contaminants. The remediation fluid may also be heated to accomplish volatile stripping of the contaminated material or to activate microbial agents in a low temperature environment.

In one aspect, the present invention is an injection treatment apparatus in situ for remediating contaminated material at a contaminated site having a trenching mechanism means with a trenching tool for continuing in situ contaminated material and a means for positioning and powering the trenching tool. The apparatus has an injection means for injecting a remediation fluid into the contaminated material in close proximity to the trenching tool comprising an injection nozzle means positioned and adapted to inject the remediation fluid below the surface of the contaminated material while the material is being comminuted by the trenching tool and a remediation fluid delivery means for conveying and delivering the remediation fluid to the injection means under pressure.

The injection means has at least one injection nozzle, preferably a plurality of injection nozzles, positioned to inject the remediation fluid into contaminated material excavated during operation of the trenching tool. The injection nozzles are preferably located at predetermined positions along the length of the trenching tool.

The remediation fluid delivery means has a remediation fluid storage means, a conduit means and a pump means for pumping the remediation fluid from the storage means through the conduit means to the injection means under pressure. Optionally, the remediation delivery means may have a heating means for heating the remediation fluid such as in the case of forced hot air.

The apparatus may also have a monitoring means for monitoring a selected physical or chemical property of the contaminated material such as pH, oxygen content, temperature or the like in the proximity of the trenching tool during operation of the apparatus and a means for adjusting the selected property of the contaminated material to a predetermined value, such as a means for adjusting the amount of a constituent remediation agent in the remediation fluid injected into the contaminated material during operation.

The apparatus may also comprise a volatile collection means for collecting volatile substances such as volatile hydrocarbons emitted from the contaminated material during treatment with the injection treatment apparatus.

In another aspect, the invention comprises a process for remediating a contaminated material at a contaminated site. The process comprises comminuting the contaminated material with a trenching tool mechanism having a trenching tool and injecting a remediation fluid into the contaminated material in the proximity of the trenching tool below the surface a process for remediating a contaminated material in situ at a contaminated site comprising:

comminuting the contaminated material with a trenching tool mechanism having a trenching tool; and

injecting a remediation fluid into the contaminated material in the proximity of the trenching tool below the surface of the contaminated material while the material is being comminuted by the trenching tool, using an amount of remediation fluid, to remediate the contaminated material to provide a remediated material. The treated material is preferably deposited into the trench excavated by the trenching tool mechanism.

Where the contaminated material comprises a volatile constituent, the remediation fluid is preferably a fluid such as hot air for volatilizing a volatile constituent which is then collected using a collection means. In the case of a liquid or semi-solid contaminated material such as a sludge or wastewater lagoon, the remediation fluid preferably comprises a solidification agent which is injected into the contaminated material thereby solidifying it and permitting further treatment. The method may also comprise monitoring a selected physical or chemical property of the contaminated material such as pH, oxygen content, temperature or the like and adjusting the selected property of the contaminated material to a predetermined value. For example, the pH may be maintained at a predetermined value by adjusting the amount of a constituent pH adjusting agent such as a pH buffer solution in the remediation fluid. The method may also comprise the step of heating the remediation fluid prior to injecting it into the contaminated material. This is useful where the remediation fluid comprises a microbial bioremediation agent and a gas such as air is heated sufficiently to activate the bioremediation agent in the contaminated material in a low temperature environment.

In a further aspect, the invention provides a process for remediating in situ a contaminated material comprising a volatile contaminant at a contaminated site comprising comminuting the contaminated material in situ with a trenching tool mechanism having a trenching tool; and injecting a gas at a temperature above a vaporization temperature for volatilizing the volatile contaminant into the contaminated material in the proximity of the trenching tool below the surface of the contaminated material while the material is being comminuted by the trenching tool to remediate the contaminated material to provide a remediated material.

Brief Description Of The Drawings

FIG. 1 is a side elevation of the trenching tool portion of the trenching tool mechanism and the injection means.

FIG. 2 is a sectional view taken through line 2-2 of FIG. 1.

FIG. 3 is a schematic diagram of a trenching tool mechanism excavating contaminated soil and injecting a

A

remediation fluid along the length of the trenching tool.

Detailed Description
Of The Preferred Embodiments

In describing a preferred embodiment of the invention illustrated in the drawings, specific terminology will be used for the sake of clarity. However, the invention is not intended to be limited to the specific terms so selected, and it is to be understood that each specific term includes all technical equivalents which operate in a similar manner to accomplish a similar purpose.

With reference to the drawings, in general, and FIGS. 1 through 3 in particular, a trenching tool mechanism 10, injection means 41 and remediation fluid delivery means are shown.

The trenching tool mechanism 10 includes a mobile unit 20 mounted on tracks 21 having a boom 22 and hydraulic piston cylinder assemblies 24 and 26 for positioning trenching tool 30. Injection system 41 having injection nozzles 40 is mounted along the length of shaft 36 of trenching tool 30. The injection nozzles 40 are positioned below a plurality of digging tools 32 mounted on conveyor chain 34. As can be seen from the drawings, the injection nozzles are positioned such that the remediation fluid is injected below the soil surface while the contaminated soil is being excavated or comminuted by the trenching tool. The remediation fluid is thereby injected in the trench in the immediate vicinity of the

excavation or comminution of the contaminated soil along the trenching tool. In operation, conveyor chain 34 is driven about sprockets 44 at the ends of shaft 36. The trenching tool 30 is capable of excavating a trench of 3 to 30 feet in depth. The mobile unit 20 may be any suitable equipment such as a skid loader, backhoe, excavator, gradall or the like. The size of the trenching tool and mobile unit will vary depending upon site conditions.

The remediation fluid is pumped from storage tank 12 through conduit 14 to injection system 41 under pressure by a pump (not shown). The injection pressure may vary from about 10 psi to about 3,000 psi depending upon the desired remediation treatment. The remediation fluid may also be heated by a heating unit (not shown). The size and number of the injection nozzles may vary in accordance with the remediation treatment. For example, the nozzle size for pressurized hot air may range from about 1" to about 4" in diameter. Nozzle size for injecting a high pressure liquid may be 1/4" or smaller. The injection system may be pressurized by any suitable power source such as a hydraulic, electric or diesel power unit.

The remediation fluid delivery system may comprise a mixing unit for mixing constituent remediation agents from a plurality of storage tanks. Alternatively, parallel systems for delivering and injecting a plurality of remediation fluids may be employed. Such an embodiment is particularly useful,

for example, when two or more different remediation fluids such as a gas and a liquid are being injected into the contaminated soil simultaneously. The parallel system permits the multiple fluids to be injected through injection nozzles of different sizes at different pressures.

In operation, the contaminated soil 60 is excavated, and thereby comminuted and agitated, by trenching tool 30 in the direction of arrow 50. During excavation, a suitable remediation fluid is pumped through injection nozzles 40 of injection system 41 into the contaminated soil. The treated soil 55 is discharged into the trench thusly excavated by trenching tool 30 behind trench guard 42. A wide area of contaminated material such as contaminated soil or sludge at a site may be treated by trenching in parallel rows or any other suitable pattern across the entire area.

Any suitable remediation fluid, such as gases, liquids, slurries, or particulate solids, may be injected into the contaminated material in accordance with the process of this invention. The choice of remediation fluid and its constituents will depend upon site conditions and the contaminants sought to be remediated. By way of example, and without intending to be limited thereto, a liquid lime solution may be injected to stabilize a lead-contaminated site. A liquid biostimulant and appropriate microorganism such as are sold by Polybac Corp. of Bethlehem, Pennsylvania may be injected to treat contaminants such as mineral oil,

glycol or chlorinated phenols. Sludges may be solidified by injecting a solidification agent such as kiln dust into the contaminated sludge. If desired, a variety of remediation agents may be used in combination. For example, an oxygenation agent such as grade D breathing air may be used in combination with a bioremediation agent to aerate and accelerate the treatment of the contaminated material.

Stripping of volatile contaminants such as acetone, toluene, isopropyl alcohol, trichloroethanol, and the like may be accomplished by injecting hot air under pressure to volatilize the contaminants. The volatile contaminants may be collected by any suitable collection system such as a tent-like structure having a positive pressure circulation system with a carbon filter. Such a collection system is available from Sprung Structures, Inc. of Allentown, Pennsylvania. The apparatus of the present invention may be sized to operate within the tent-like structure.

The present invention may be used to remediate contaminated sites which were heretofore untreatable. For example, bioremediation of contaminated soil may not, in general, be achievable in low temperature environments, typically environments having temperatures below about 40° F. The low temperatures tend to incapacitate or kill the microorganisms that accomplish the remediation. However, the present method provides for the injection of a heated gas such as hot air in combination with the bioremediation agent

thereby raising the temperature at the locus of treatment and activating the bioremediation agent. This has the beneficial effect of permitting bioremediation of contaminated soils in cooler or arctic climates and/or extending the effective season during which bioremediation may be accomplished in temperate climates.

In another instance, the present invention provides for the injection of remediation fluids in dense, clay-laden soils. The prior art methods of injection are ineffective in treating non-porous, clay-laden soils, because the injected remediation fluid is unable to migrate throughout the soil. However, according to the present invention, clay-laden soils may be effectively remediated, because the method comminutes the soil during excavation by the trenching tool.

The present invention is principally intended for the treatment of contaminated soil. However, a wide variety of contaminated materials, including semi-solid sludges and wastewater lagoons, may be treated in accordance with the invention. In the case of a lagoon, the injection treatment apparatus may act as a kind of large-scale, mobile mixer for agitating and injecting a remediation fluid into the wastewater. The wastewater may be first treated to neutralize contaminants in the water, and subsequently treated with a solidification agent. Alternatively, the wastewater may be first injected with a solidification agent to form a contaminated "soil", and then injected with a second

remediation fluid to neutralize the contaminants.

Although this invention has been illustrated by reference to specific embodiments, it will be apparent to those skilled in the art that various changes and modifications may be made which clearly fall within the scope of the invention. The invention is intended to be protected broadly within the spirit and scope of the appended claims.

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What is claimed is:

1. An injection treatment apparatus for remediating a contaminated material in situ at a contaminated site comprising:

a trenching mechanism means comprising a trenching tool for comminuting in situ contaminated material and a means for positioning and powering the trenching tool;

an injection means for injecting a remediation fluid into the contaminated material in close proximity to the trenching tool comprising an injection nozzle means positioned and adapted to inject the remediation fluid below the surface of the contaminated material while the material is being comminuted by the trenching tool; and

a remediation fluid delivery means for conveying and delivering the remediation fluid to the injection means.

2. An apparatus according to claim 1, wherein the injection means comprises at least one injection nozzle positioned to inject the remediation fluid into contaminated material excavated during operation of the trenching tool.

3. An apparatus according to claim 2, wherein the injection means comprises a plurality of injection nozzles.

4. An apparatus according to claim 3, wherein the injection nozzles are located at positions along the length of the trenching tool.

5. An apparatus according to claim 1, wherein the remediation fluid delivery means comprises a remediation fluid storage means, a conduit means and a pump means for pumping the remediation fluid from the storage means through the conduit means to the injection means under pressure.

6. An apparatus according to claim 5, wherein the remediation delivery means further comprises a heating means for heating the remediation fluid.

7. An apparatus according to claim 1, wherein the injection treatment apparatus further comprises a monitoring means for monitoring a selected physical or chemical property of the contaminated material in the proximity of the trenching tool during operation of the apparatus and a means for adjusting the selected property of the contaminated material to a predetermined value.

8. An apparatus according to claim 7, wherein the means for adjusting the selected property comprises a means for adjusting the amount of a constituent remediation agent in the

remediation fluid injected into the contaminated material during operation of the apparatus.

9. An apparatus according to claim 1, wherein the apparatus further comprises a volatile collection means for collecting volatile substances emitted from the contaminated material during treatment with the injection treatment apparatus.

10. A process for remediating a contaminated material in situ at a contaminated site comprising:

comminuting the contaminated material with a trenching tool mechanism having a trenching tool; and

injecting a remediation fluid into the contaminated material in the proximity of the trenching tool below the surface of the contaminated material while the material is being comminuted by the trenching tool, using an amount of remediation fluid, to remediate the contaminated material to provide a remediated material.

11. The process of claim 10, wherein the process further comprises the step of depositing the remediated material back into a trench from which the material has been lifted and comminuted by the trenching tool mechanism.

12. The process of claim 10, wherein the remediation fluid comprises a fluid for volatilizing a volatile contaminant in the contaminated material, and the process further comprises the step of collecting the volatilized volatile contaminant.

13. The process of claim 10, wherein the contaminated material is a liquid or semi-solid, and, prior to the comminution step, a solidification agent is injected into the contaminated material while the liquid or semi-solid contaminated material is being agitated by the trenching tool.

14. The process of claim 13, wherein the remediation fluid and solidification agent are injected into the contaminated material simultaneously.

15. The process of claim 10, wherein the process further comprises the steps of:

monitoring a selected physical or chemical property of the contaminated material; and

adjusting the selected property of the contaminated material to promote suitable conditions for remediation of the contaminated material.

16. The process of claim 15, wherein the selected property is the pH of the contaminated material, and the pH is maintained at a value suitable for promoting remediation of the contaminated material by adjusting the amount of a constituent pH adjusting agent in the remediation fluid.

17. The process of claim 10, wherein the process further comprises the step of heating the remediation fluid to a temperature sufficient to volatilize volatile contaminant in the contaminated material prior to injecting it into the contaminated material.

18. The process of claim 10, wherein the contaminated material comprises bioremediation agent.

19. The process of claim 18, wherein remediation fluid comprises a heated gas to accelerate biological decontamination of contaminants in the contaminated material.

20. The process of claim 10, wherein the remediation fluid comprises a composition for encapsulating a contaminant in the contaminated material.

21. The process of claim 10, wherein the remediation fluid comprises a zeolitic compound and the remediation fluid serves to encapsulate a contaminant in the contaminated fluid.

22. The process of claim 18, wherein the remediation fluid comprises a constituent selected from the group consisting of contaminant-degrading bacterial microorganisms, bionutrients, water, air, oxygen and mixtures thereof and is suitable for stimulating the growth of contaminant-degrading microbes.

23. The process of claim 18, wherein the remediation fluid comprises white rot fungus.

24. The process of claim 23, where the remediation fluid comprises a biostimulant suitable for stimulating the growth of contaminant-degrading white rot fungus selected from the group consisting of lignin, cellulose, wood shavings, sawdust, corn cobs, humus and mixtures thereof.

25. The process of claim 12 wherein the remediation fluid for volatilizing the volatile contaminant comprises air heated to a temperature of between about 200°F and about 550°F.

26. The process of claim 12, wherein the remediated fluid is a gas at a temperature above a vaporization temperature for volatilizing the volatile component.

27. The process of claim 26, wherein the remediation fluid is air.

28. A process for remediating in situ a contaminated material comprising a volatile contaminant at a contaminated site comprising:

comminuting the contaminated material in situ with a trenching tool mechanism having a trenching tool; and

injecting a gas at a temperature above a vaporization temperature for volatilizing the volatile contaminant into the

contaminated material in the proximity of the trenching tool below the surface of the contaminated material while the material is being comminuted by the trenching tool to remediate the contaminated material to provide a remediated material.

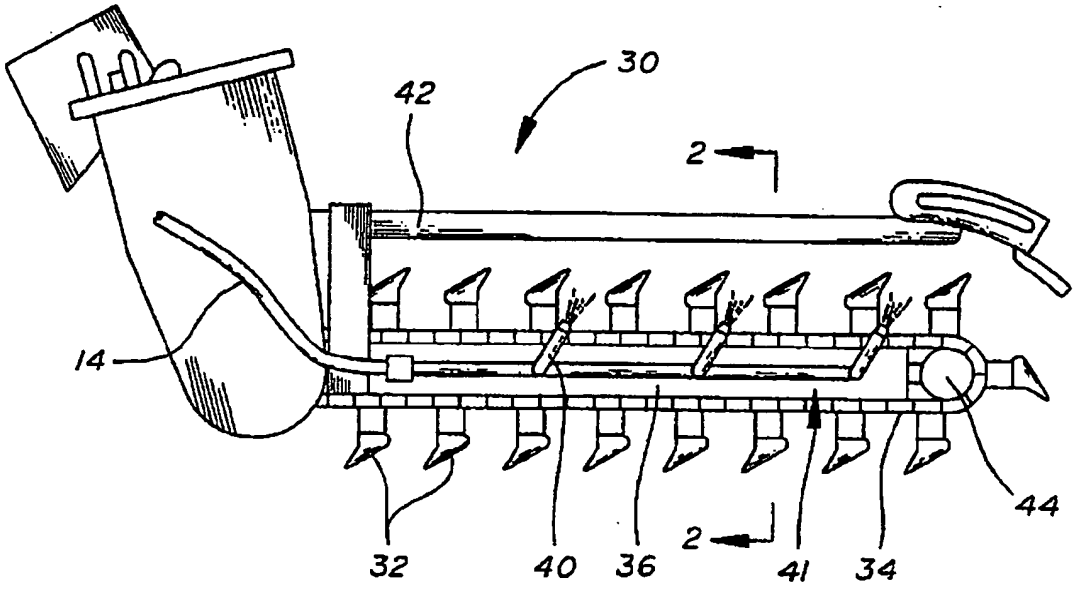

Fig. 1

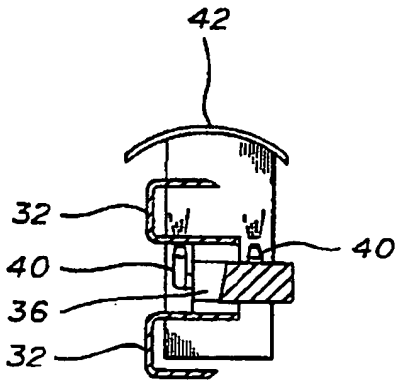

Fig. 2

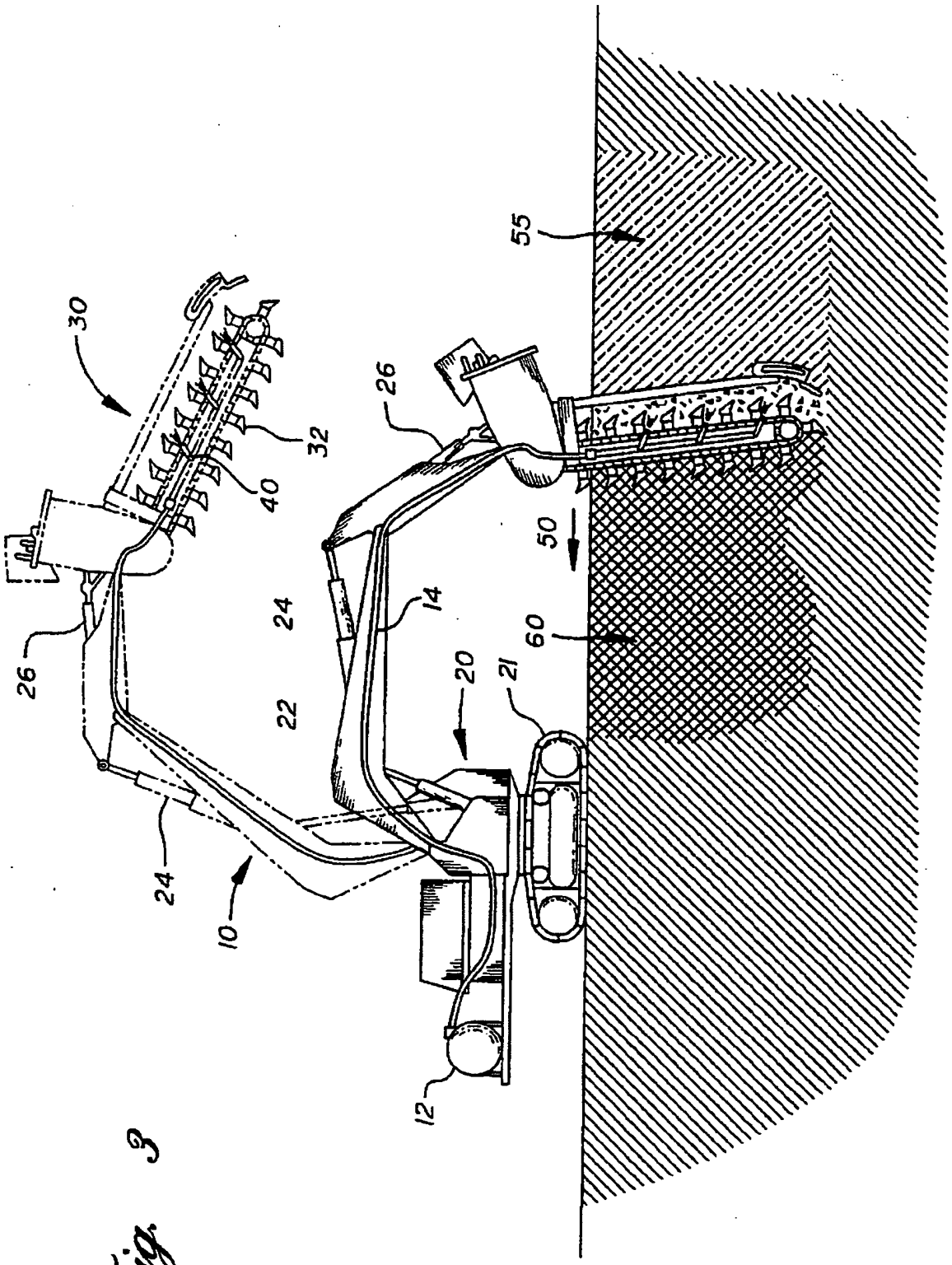

Fig. 3